

What eye-tracking can teach us about language processing

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Overview

- The basics of eye-tracking
- Eye-tracking in (psycho-)linguistic research
- Eye-tracking in natural language processing

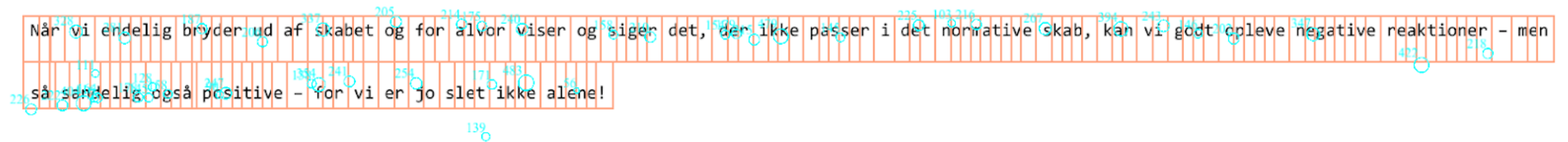
Kære Alle

Mit navn er Andrea Rygg Karberg, og jeg startede 1. juni som ny direktør for Nivaagaards Malerisamling. Mine første 23 dage har været forrygende travle, skægge og glade. Jeg har set frem til at opleve også denne her smukke Nivaagaard-tradition, og jeg blev meget beæret, da jeg blev bedt om at holde årets bårtale. En bårtale er jo sådan en slags frit emne, så jeg har haft mange forskellige ideer - og jeg er endelig med at ville tale om en række H'er: Sankt Hans - hedenskab - hekse - og Holger Drachmann.



Eye-tracking features

Når vi endelig bryder ud af skabet og for alvor viser og siger det, der ikke passer i det normative skab, kan vi godt opleve negative reaktioner - men så sandelig også positive - for vi er jo slet ikke alene!

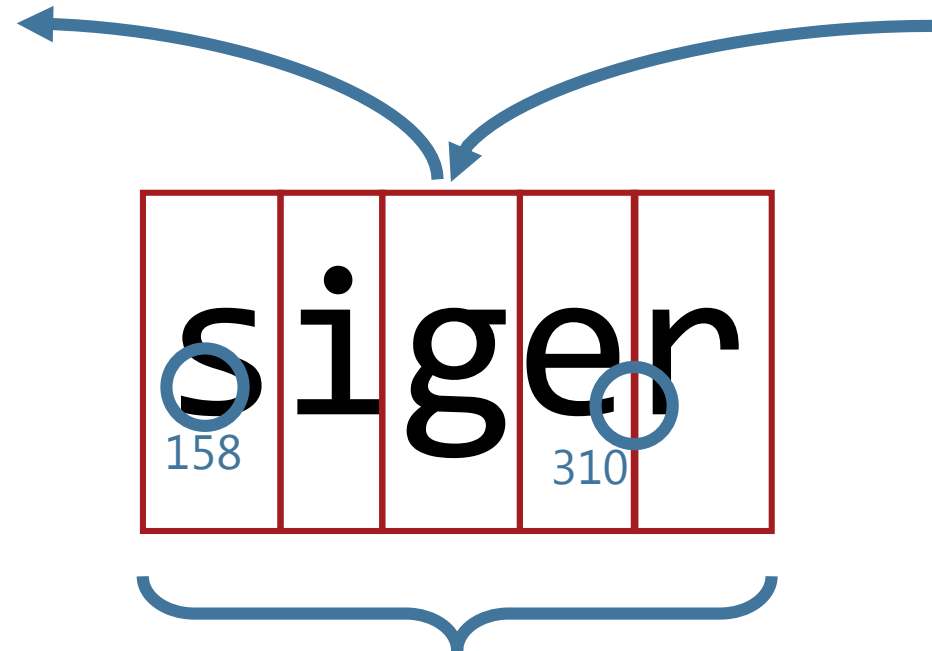


The image displays an eye-tracking visualization over a two-line text block. The text is enclosed in a grid of orange rectangular cells. Blue circles of varying sizes are placed over the text, with numbers above them representing the duration of gaze in milliseconds. The numbers are distributed across the text, with higher concentrations on the first line, particularly around the words 'skab' and 'reaktioner'. The second line also shows several gaze points, with a notable one at the end of the sentence.

Approximate X-Coordinate	Approximate Y-Coordinate	Gaze Duration (ms)
100	470	118
150	470	187
200	470	107
250	470	205
300	470	214
350	470	240
400	470	58
450	470	150
500	470	110
550	470	225
600	470	103
650	470	216
700	470	207
750	470	321
800	470	245
850	470	146
900	470	147
950	470	421
980	470	218
100	530	111
150	530	128
200	530	247
250	530	135
300	530	241
350	530	253
400	530	171
450	530	483
500	530	54
320	580	139

Eye-tracking features

- First fixation duration
- Landing position
- Mean fixation duration
- Saccades from/to word w
- Total reading time
- ...



→ provides information on all levels of text processing

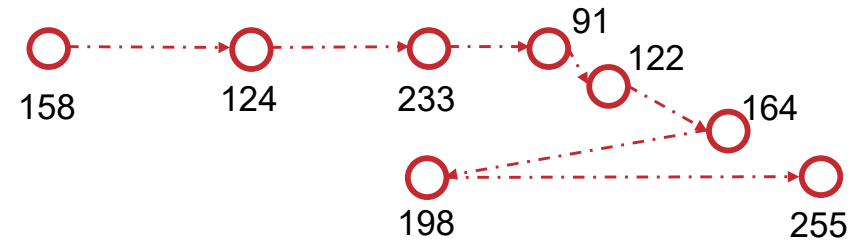


Eye-tracking to study language processing

Psycholinguistics & reading research

- Online, real-time metrics of natural reading in an ecologically valid experiment set up
- Skipping behavior may indicate ease of processing
- Longer reading times may indicate confusion or difficulty
- Long regressions may indicate difficulty in incorporating context

Laurance married Mary French in 1934.



→ insights into cognitive processing efforts, learning behavior and engagement

Applications

- Dyslexia & reading difficulties
 - Improve educational materials and learning processes
 - Insights by reading naturally
 - Taking into account individual differences
- Cross-linguistic differences
 - Native speakers vs. bilinguals vs. language learners
 - Language-specific reading and comprehension characteristics
- Machine learning
 - Predicting native language
 - Predicting proficiency
 - Classifying text readability

Eye-tracking for **natural** language processing

The potential of eye-tracking in NLP

Improving NLP models

- Fortuitous data: more robust models
- Availability
 - Relatively easy to collect
 - Existing datasets in various languages
- Readiness
 - Behavioral online metrics
 - Preprocessing required

Understanding NLP models

- When is a language model cognitively plausible?
 - Psycholinguistics: If it exhibits similar processing patterns as humans
 - NLP: If it makes similar decisions as humans
- “A window on mind and brain”
- Reflects human text processing

Improving NLP models with eye-tracking data

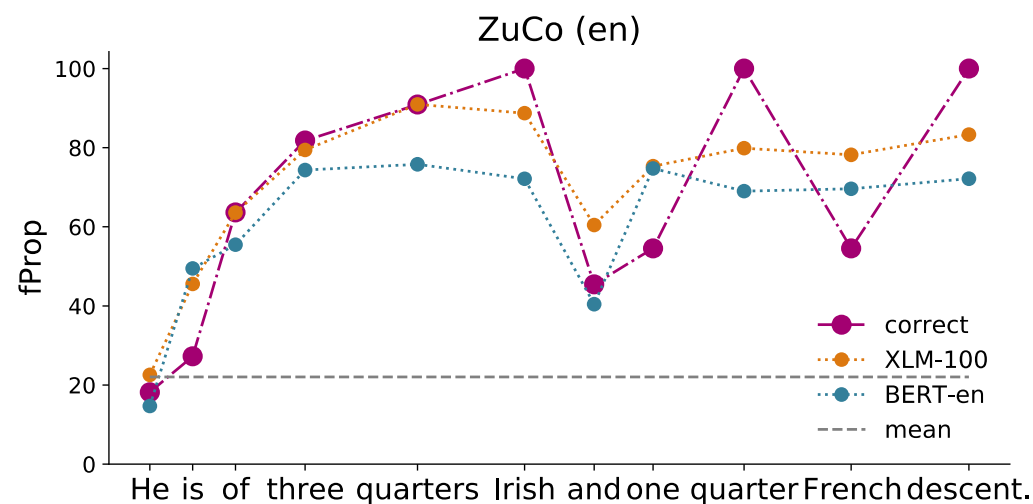
- **Multi-modal** models: learning from text and eye movements
- **Multi-task** approaches
- Modest but **consistent improvements** on various level of text processing
- **Challenge:** preprocessing decisions

NLP task	Earliest reference
Part-of-speech tagging	Barrett et al. (2016a)
Sentiment analysis	Mishra et al. (2017b)
Named entity recognition	Hollenstein & Zhang (2019)
Relation detection	Hollenstein et al. (2019a)
Sarcasm detection	Mishra et al. (2016)
Multiword expressions	Rohanian et al. (2017)
Referential/non-referential <i>it</i>	Yaneva et al. (2018)
Coreference resolution	Cheri et al. (2016)
Sentence compression	Klerke et al. (2016)
Predicting misreadings	Bingel et al. (2018)
Predicting native language	Berzak et al. (2017)
Predicting language proficiency	Kunze et al. (2013)
Dependency parsing	Strzyz et al. (2019)
Text summarization	Xu et al. (2009)

Analyzing NLP models with eye-tracking data

Predicting human reading behavior metrics

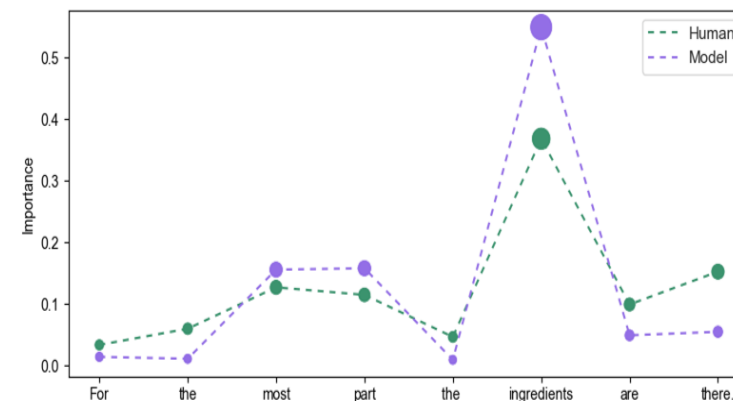
Can computational language models predict human language processing signals?



Hollenstein et al., 2021

Correlating computational and human language processing

How well do the weights learned by computational language models correlate with human patterns of language processing?



Hollenstein & Beinborn, 2021

Outlook ∞∞

- Eye-tracking provides online metrics of language comprehension on multiple levels of analysis
- Potential of using eye movements to build more robust NLP models
- Possibility to adjust the inductive bias of neural models towards more cognitively plausible outputs.

→ better understanding of the similarities and differences between human and machine language processing

Danish eye-tracking data

CopCo: The Copenhagen Corpus of Eye-tracking Recordings from Natural Reading

- Naturalistic reading of continuous text
- Cross-linguistic analysis of reading pattern
- Applications in psycholinguistics *and* NLP

- Participants welcome 😊
 - 1st release: native speakers
 - 2nd release: second language speakers

Thank you!



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